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SOME PROBABLE IDENTITIES IN WAVE-LENGTH IN NEBULAR AND STELLAR SPECTRA*

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Presented to the Academy, October 22, 1915

Coincidence between the bright nebular lines and lines in the spectra of the stars and terrestial sources are usually regarded as limited to the radiations of hydrogen, helium, the line at wave-length 4686A, and the related series of ζ *Puppis* lines. There are other correspondences to which attention should be drawn. There is in the nebulae a very faint line close to $H\delta$ which became pronounced enough in the spectrum of *Nova Geminorum* no. 2 to modify very perceptibly the form of the H_δ band. In fact it was first suspected in the *nova* from this circumstance, and afterward found, with prolonged exposure, in a number of nebulae. Its wave-length is uncertain on account of its faintness and the over-powering strength of the H_δ line which, with the low dispersion used, is very close. The mean of five measures gives 4097.6A. The wave-length of the dark line in ε *Orionis* is, according to R. H. Curtiss,[1] 4097.5A. This stellar line has been the subject of much discussion in studies of spectral classification. It has its maximum, according to Miss Cannon, in Class Oe stars. It has been assigned by various observers to as many elements, but the best case seems to have been made out by Lockyer, Baxendall and Butler who identify it with a line of abnormal behavior in the spectrum of nitrogen.[2] Whatever its chemical source its strength in Class O stars argues for its common origin in these and in the nebulae.

A line which plays an equally, or perhaps more, important part in stars a little further along in their development is 4267.30A. This is universally ascribed to carbon, and the wave-length quoted is Hartmann's laboratory determination made with a highly rarefied tube containing a gaseous hydrocarbon compound. A faint nebular line has been photographed in this vicinity by several observers, but only rough determinations of its position have been published. The mean of five of my measures places it at 4267.28A. The line is very faint and this value may be in error, say 0.2 of an angstrom. The South Kensington observers have found[3] the carbon line 4267.30 to be accompanied by a doublet in position 4647.53, 4650.92. If this doublet were in the nebulae it would not be resolved on these plates but would be represented by an apparently single line of slightly greater wave-length than the mean, as the red component of the double is the stronger of the two. In other words a nebular line of slightly greater wave-length than 4649.2A would meet the requirements. There is actually such a line at 4649.5A. Both this and the one at 4267A probably exist as bright bands in the spectra of the Wolf-Rayet stars.[4]

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* See note on previous title, p. 590.

The following is a summary of the wave-length comparisons which have been made:

Nebula	*Star.*	
	Nitrogen	*Carbon*
4097.6	4097.5	
4267.28±		4267.30
4649.5		4649.2 +

In considering the significance of these comparisons it should be borne in mind that the observations of the nebulae were made with a single prism spectrograph and that the lines are faint and difficult to measure. I think, however, that the evidence renders probable the presence in the nebulae of carbon and nitrogen, and fortifies the assumption of a close relationship between the nebulae and the early type stars.

There are other possible points of correspondence between nebular and stellar spectra which will be referred to in a more complete presentation of the subject.

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[1] *Pub. Ast. Obs. Univ. Mich.*, 1, 120 (1915).

[2] *London, Proc. R. Soc.*, A, 82, 534 (1909).

[3] *Ibid.*

[4] A paper is just at hand by Mr. T. R. Merton, entitled: On a spectrum associated with carbon, in relation to the Wolf-Rayet stars, *Lond., Proc. R. Soc.*, A, **91**, 498 (1915). In this the author makes the suggestion that the two Wolf-Rayet bands in question, with others, are due to carbon.

ENERGY TRANSFORMATIONS DURING HORIZONTAL WALKING

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Presented to the Academy, November 2, 1915

No form of muscular exercise enters so universally into the lives of all individuals as does horizontal walking, but most of the earlier researches on the energy transformations consider walking on a horizontal plane as incidental to or as a base-line for the work of ascent, particularly in connection with mountain climbing. From the fundamental contributions of Zuntz and Durig and their associates, it has been concluded that for an individual walking on a horizontal plane the energy required to move one kilogram, either of body-weight or of